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Relationship Between Fat Content of Dairy Grain Mixtures and Milk and Butterfat Production

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RELATIONSHIP BETWEEN FAT CONTENT OF DAIRY GRAIN MIXTURES AND MILK AND BUTTERFAT PRODUCTION

C. F. MONROE AND W. E. KRAUSS

INTRODUCTION

The introduction of new feeds creates new problems in feeding. These new feeds, arising as they often do from economic necessity, frequently afford an opportunity for reducing feed costs. Thus, the rapid increase in the amount of soybeans produced and processed has made available to dairymen a large amount of soybean oil meal, a feed suitable as a high-protein supplement. When the meal is produced by either the expeller or the hydraulic process, its fat content is moderately high. When the meal is produced by the extraction process, the fat content is extremely low. When extracted meal is combined in a grain mixture, the resulting mixture will be lower in fat than when meals from the expeller and hydraulic processes or other common high-protein supplements are used. Since fat has been shown to have some function in milk production (18), the question may be raised as to the effect of using high-fat or low-fat protein supplements or, more specifically, the effect of the level of fat in grain mixtures on milk production. The experiments here described were designed to throw some light on this question, under practical feeding conditions.

The trials reported were planned to determine the production performance resulting from use of grain mixtures representing the levels of fat most often contained in ordinary feeds. Although the differences in fat levels in this work were not so large as in some of the work of other investigators, it is believed that the levels used are applicable except when large quantities of soybeans are fed. In other points also, the general plan has been to conform to practical feeding and management conditions, including the feeding of liberal amounts of legume hay with corn silage and the use of long feeding periods, of 100 days and more.

REVIEW OF THE LITERATURE

The early work of Jordan and associates (12, 13) on the "Source of Milk Fat" showed that a cow could use the carbohydrate material in the ration for the production of milk fat. This finding was generally interpreted to mean that fat was not essential to the dairy ration. However, there was no attempt made in this work to demonstrate that rations nearly devoid of fat were as efficient as those containing a normal amount.

Maynard and McCay (17) showed that grain mixtures from which most of the fat had been removed by extraction with benzine were not as efficient for milk and butterfat production as the unextracted mixtures. The grain mixtures before extraction contained 6 or 7 per cent fat and after extraction less than 1 per cent. An intermediate mixture obtained by blending the two and containing 3 per cent fat gave higher production than the low-fat, but not as good as the high-fat, mixture.

In another series of trials Maynard and associates (18) compared grain mixtures containing 4 and 7 per cent of fat. In these trials a mixture of high-fat grains was specially fat-extracted for adding to a basal mixture to obtain a low-fat level and added without extraction for the high-fat level. The authors concluded that "While the differences in milk and butterfat yield were generally in favor of the higher fat level, they were too small to be considered significant."

In two other trials Maynard and associates (14) extracted a single feed to obtain a low-fat mixture. Two grain mixtures were made up similarly with the exception that one contained ground soybeans and the other a solvent-extracted soybean oil meal. The high-fat mixtures contained 6.27 and 6.33 per cent fat; the low-fat mixtures, 3.35 and 3.09 per cent. The results of one of these trials showed no significant difference, but in the other trial, there was a significant difference favoring the high-fat mixtures.

Continuing this study of the fat requirements, Maynard and associates (16) have conducted two trials in which the fat was removed from certain feeds by either the expeller or the hydraulic process rather than by extraction with a solvent. The fat in the grain mixtures amounted to 3 and 7 per cent. The results favored the higher fat feeding, although the margin of difference was not equally pronounced in the two trials.

This work has been summarized in tabular form by Maynard and coworkers (15). In general, the results have shown an advantage for the high-fat rations, although not in all cases has the difference been significant. Excepting the two trials in which the low-fat rations contained 1 per cent or less fat, the average increase in 4 per cent milk production credited to high-fat rations was 1.5 pounds daily per cow for five reversal trials and 1 pound for three continuous feeding trials. These differences probably represent the maximum to be expected, as the cows used in this work were generally high producers, some yielding as much as 70 pounds of milk per day. For most of the work the cows were on a high plane of feeding and at the flush of lactation.

Gibson and Huffman (8) obtained a temporary increase in butterfat test and an increase in milk production by using soybean oil to replace an isodynamic amount of beet pulp in a low-fat ration. The authors state that in previous unpublished data, " the addition of fats to rations containing corn and corn silage failed to bring about an increase in either milk or percentage of butterfat." A repetition of the work (11) involving the addition of soybean oil to rations low in fat failed to bring about an improvement in milk production and in many instances resulted in a decrease in the percentage of fat. In work in which rumen digestion was studied, Hale, Duncan, and Huffman (9) found an increase in true fat in the rumen over that eaten in the feeds. A synthesis of fat in the rumen by microorganisms was suggested.

Cannon and coworkers (5) reported a series of experiments in which different levels of fat intake were attained by feeding soybeans in comparison with soybean oil meal. They stated, "We must conclude that the feeding of whole soybeans is likely to increase the percentage of butterfat in the milk and the total yield of butterfat, but it may decrease the yield of milk."

Schubert and Wells (21) failed to get an increase in milk, fat, or 4 per cent fat-corrected milk when they changed a group of cows from a low-fat grain mixture to a moderately high-fat mixture. The low-fat mixture contained 1.3 per cent fat, and the high-fat mixture contained 4.75 per cent. In

the low-fat mixture, ground barley was supplemented with extracted soybean oil meal, and in the high-fat mixture, the barley was supplemented with ground soybeans.

It has been shown by Allen (1) that the fat content of milk could be increased during 6-day periods of feeding butterfat, lard, tallow, linseed oil, corn oil, peanut oil, soybean oil, and cocoanut oil. The amount of increase was somewhat proportional to the amount of fat or oil fed. A continuation of this work, using 50-day periods (2), indicated that the increases were sustained with the increased fat feeding except when soybean oil and corn oil were fed. It is suggested that corn oil and soybean oil possess a depressing agent which may be slow in exerting its influence. Similar work conducted by Garner and Sanders (7) gave results in general agreement with these findings. Sutton and coworkers (23) failed to find any significant changes in milk and butterfat production as the result of feeding corn oil. They did find a change in the composition of the butterfat produced. Hill and Palmer (10) have also demonstrated that the character of the butterfat can be influenced by feeding different fats and oils.

A review of the work on the effect of feeding various fats and oils on milk and butterfat production and butterfat tests is given by Espe (6). The experimental work on feeding soybeans and soybean oil meal has also been reviewed (20). A further review, therefore, seems unnecessary here.

A summary of the literature on the fat requirements for milk production shows a slight advantage for higher fat rations but the results have not been entirely consistent. A rather small average increase of 1 pound of 4 per cent milk daily has been obtained by feeding grain mixtures relatively high in fat to liberally producing cows close to their peak of production. The literature also shows that temporary changes in butterfat tests and butterfat production may accompany the introduction of increased amounts of fat into the ration. Hence, in short-time reversal experiments, these temporary increases may unduly influence the results.

EXPERIMENTAL PROCEDURE

Six different feeding trials have been conducted in the experiment reported. These are listed in this report by number according to the general sequence in which they were started, with one minor exception. The first five trials were of the continuous type, with an extended feeding period; the sixth was of the reversal type, with comparatively short feeding periods. Trials 1 and 2 were conducted the first year, the rest the second year. The same general procedure was used both years. This procedure is outlined for the first year's work, and detailed changes made in procedure the second year are pointed out in the discussion of that year's work.

FIRST YEAR'S TRIALS

Trials 1 and 2 were conducted at the Grafton State Farm with the Holstein herd located there. These two trials were duplicates of each other except that in the second trial different cows and new feeds were used.

GRAIN MIXTURES

The same formulas were used for the grain mixtures in both trials. These are shown in table 1 with the average analyses of total protein and fat. The three different levels of fat represented in these grain mixtures were obtained

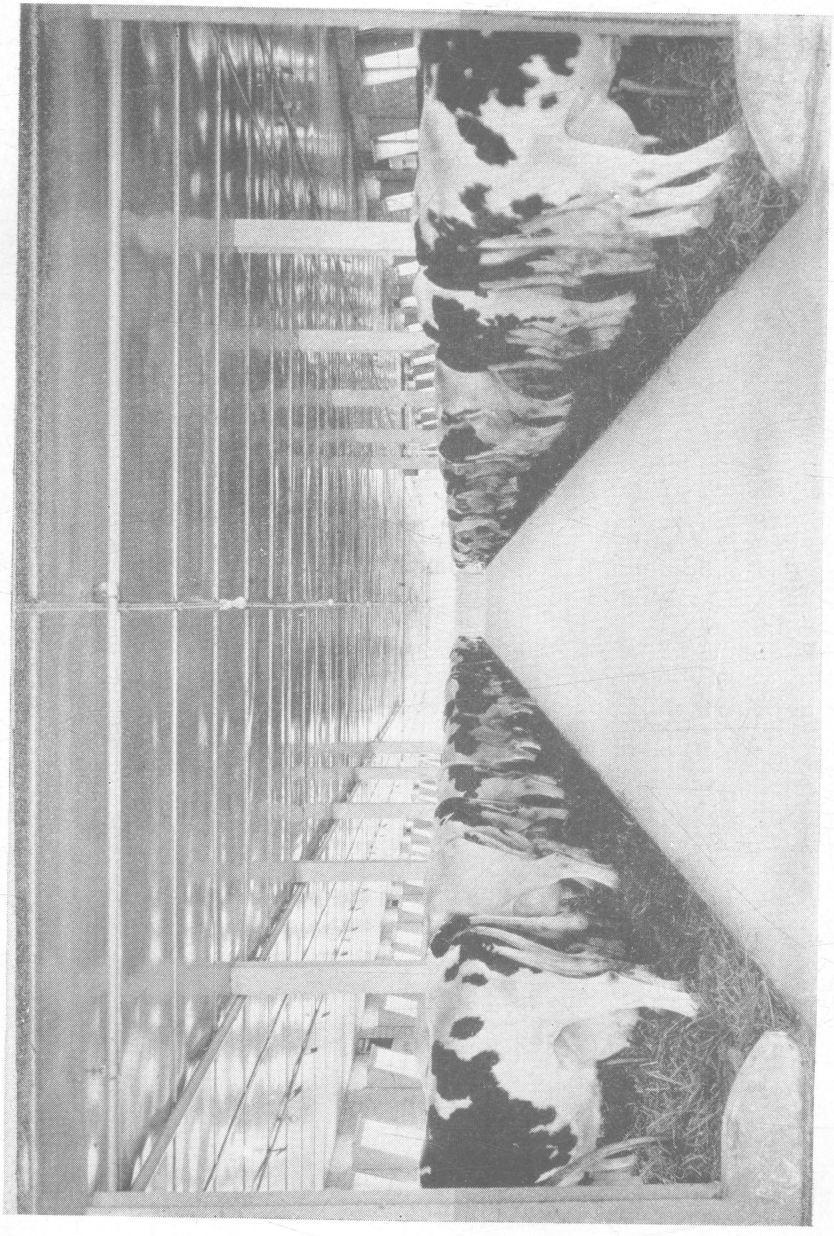

Fig. 1.—Interior of the barn and the cows used in the Grafton experiment

by using natural and by-product feeds available on the market. In general, the grain mixtures were nearly identical, except in the protein supplement. The high-fat mixture, averaging 4.73 per cent fat, contained as protein supplements ground soybeans, expeller soybean oil meal, and a small amount of linseed oil meal. The medium, or 3.54 per cent fat mixture, contained only expeller soybean oil meal. The low-fat mixture contained only extracted soybean oil meal and averaged 2.69 per cent fat. It should be pointed out that the comparison of these grain mixtures represents a comparison not only of different fat levels, but also of the different protein supplements themselves. Actually, the protein supplements were compared on the basis of the total protein furnished rather than on a weight basis. To equalize the protein content of the mixture, slight adjustments in the amounts of corn and wheat bran were necessary. These differences are shown in table 1A. The mixtures here shown can be considered as "experimental supplements", or the points of difference between the grain mixtures used in trials 1 and 2.

TABLE 1.—Grain mixtures used in trials 1 and 2, with average protein and fat in percentages

	High fat	Medium fat	Low fat
	Lb.	*Lb.*	*Lb.*
Corn-and-cob meal	800	800	820
Ground oats	350	350	350
Wheat bran	250	300	300
Molasses feed*	300	300	300
Linseed oil meal	50	.....	.....
Ground soybeans	200	.....	.....
41 per cent (expeller) soybean oil meal	.....	200	.....
44 per cent (browned extracted) soybean oil meal	.....	.....	180
Minerals and salt†	50	50	50
Total	2,000	2,000	2,000
Total protein:			
First experiment, per cent	15.19	15.78	16.07
Second experiment, per cent	15.94	15.50	15.63
Average, per cent	15.57	15.64	15.85
Total fat:			
First experiment, per cent	4.69	3.42	2.79
Second experiment, per cent	4.77	3.65	2.58
Average, per cent	4.73	3.54	2.69

*Composed of 53 per cent soybean oil meal, 27 per cent molasses, and 20 per cent dried beet pulp. In the high- and medium-fat mixtures, 41 per cent (expeller) soybean oil meal was used, and in the low-fat mixture, 44 per cent (browned extracted) soybean oil meal was used.

†Minerals and salt: 50 lb. per ton of feed mixture composed of salt, 20 lb., steamed bone meal, 20 lb., and finely ground limestone, 10 lb.

TABLE 1A.—Experimental differences in the grain mixtures shown in table 1

	High fat	Medium fat	Low fat
	Lb.	*Lb.*	*Lb.*
Corn-and-cob meal	.....	.....	20
Wheat bran	.....	50	50
Linseed oil meal	50	.....	.....
Ground soybeans	200	.....	.....
41 per cent (expeller) soybean oil meal*	159	359	.....
44 per cent (browned extracted) soybean oil meal	.....	.....	339
Total	409	409	409

*See footnote of table 1 for explanation on the soybean oil meals.

Because of the large number of animals used, it was necessary to mix new batches of feed at 4- or 5-day intervals. Feeds like corn, oats, and soybeans were ground as needed. The other components of the grain mixtures, which were purchased, were obtained in two shipments for each trial. In this way, fresh feeds and freshly mixed feeds were used throughout.

METHODS OF ANALYSIS

Samples for analysis were taken from each batch of feed mixed, as well as from the individual components, except the purchased ingredients, the entire shipments of which were sampled. These individual samples were later composited. All the analyses were made on the composite samples. The analytical results are shown in appendix tables 1 and 2.

The analytical methods employed were those recommended by the Association of Official Agricultural Chemists (3) for grain and stock feed. For the determination of crude fat, the direct procedure, in which the extracted fat is weighed, was used. Petroleum ether (35°-60° C. b.p.) was used for the solvent, as results with this solvent were more reliable than those with ethyl ether, especially for the samples of soybeans and soybean oil meals.

Butterfat tests were made twice each month on composite samples representing a day's production for each cow. In this way it was possible to test fresh, rather than preserved, milk and to avoid the complications involved in using preserved samples.

Statistical analyses of the results have been made according to the methods outlined by Snedecor (22).

FEEDING

Grain.—The amount of grain given each animal was weighed and recorded for each feeding, also the amount of grain refused. The grain was fed at approximately the rate of 1 pound for every 3⅓ pounds of milk produced

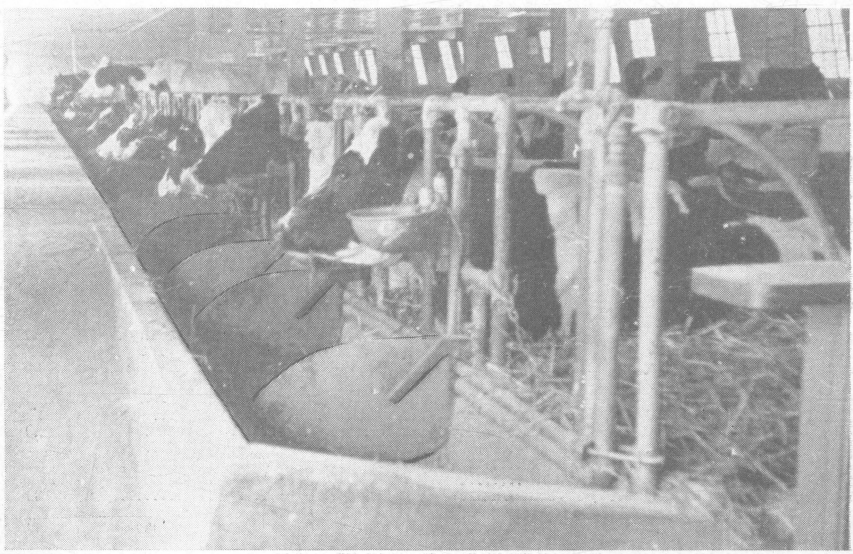

Fig. 2.—View showing the partitions used to prevent the cows' eating each other's grain

daily, with adjustments at approximately weekly intervals. Very little difficulty was experienced with cows' refusing their quota of grain. If an individual showed signs of "slowing up", either her allowance was reduced, or the grain feeding was discontinued entirely for one or two feeds, so that there was very little refuse grain. Manger divisions between cows reduced stealing of grain to a negligible amount.

Hay.—The cows were given all the hay they cared to eat. The amounts fed were not weighed. In general, the hay, a mixture of alfalfa, clover, and timothy, was of fair to good quality. Because of the large number of cows and the great amount of hay consumed, the hay from any one source and of any one kind lasted only a short time. Hence there were a number of different hays fed, and some of the time more than one kind was used during a single day.

Silage.—For the first 32 days of trial 1, hay silage was fed. This was the only hay silage fed in the entire work. Corn silage was fed after this and throughout the remaining trials. The amount fed was limited to approximately 30 pounds per day, divided into three equal feedings for each cow. This amount was not weighed out at each feeding. Check weighings were made at intervals to determine the volume of silage to give each cow to make the desired weight of 10 pounds per feeding.

Pasture.—At the beginning of trial 1 the cows were on pasture. Several different types of pasture were used, and for some of the time more than one type was grazed during the day. While on pasture, the cows received supplemental feeding of grain, hay, and silage in the barn, as the amount of feed supplied by the pasture was not large. The first trial was the only one in which pasture was involved, and it was used for only a short time at the beginning of the trial, or in the preliminary period. In all other trials, the work was conducted under strictly barn feeding conditions.

MANAGEMENT

The cows were all fed and milked by machine three times daily throughout the trials, as had been the regular herd practice. When in the barn, the cows were kept in tie stalls provided with drinking cups. The stalls were kept well bedded with straw. During the pasture season, in trial 1 the cows were turned out for grazing twice a day, and for the remainder of the time when not on pasture, they were turned out for exercise each day in the barnyard.

FEEDING PERIODS

The continuous system of experimental feeding described by Maynard and Myers (19) and later studied experimentally by Bartlett (4) was followed. In the continuous system, all the cows are given identical treatment throughout a preliminary period, then allotted to groups and fed experimental rations without change for an extended period of time, a method that corresponds to practice more closely than the change-over type of trial. In calculating the results, the performance during the preliminary period is of value in determining the differences due to experimental treatment. In trials 1 and 2 of this work, the preliminary periods were 50 days, and the experimental periods were 110 days each. The first 10 days of these periods were considered as transitional, and the data obtained in them were not included in the final summaries. In the preliminary periods of trials 1 and 2, all the cows were fed the high-fat

grain mixture, the same as later fed to the cows on the high-fat ration. The high-fat group, therefore, received no change in feeding throughout the 160 days of the trials.

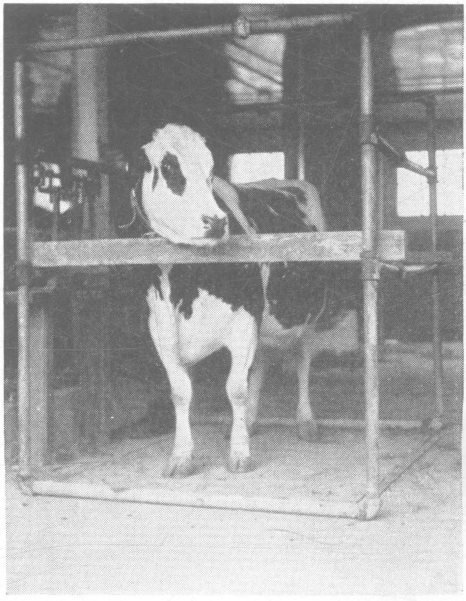

Fig. 3.—Scale used for weighing the cows

METHOD OF ALLOTMENT OF COWS

Toward the close of the preliminary periods the cows were matched in groups of three. In matching, an attempt was made to have the sets of three as nearly alike as possible in age, production, stage of lactation and gestation, and liveweight. After the sets were made up, one of each was allotted to a group. To these groups there was then assigned one of the experimental grain mixtures. Assignments were made according to lots drawn by a disinterested person. In general, the groups were fairly equal. The small differences between groups apparently favoring a certain level of fat in one trial were compensated for in the other trials, so that in the complete series of five trials reported, the different fat levels were fed to approximately equal groups of cows. Appendix table 6 gives the average age, stage of lactation and gestation, and the liveweights of the cows in the various groups in trials 1, 2, 3, 4, and 5.

RESULTS OF FIRST YEAR'S TRIALS

The results of each trial are contained in a brief text description accompanied by a summary table. In the summary tables are shown the average production of milk and butterfat calculated to a 30-day basis for both the preliminary and the experimental periods, as well as production on the basis of 4 per cent (F. C. M.) milk. Liveweight gains and feed intakes are also given.

The differences between the preliminary and experimental periods for the different items are presented at the bottom of each table, and on the last line will be found the ratio of the production of 4 per cent milk between the two periods. The ratio has been obtained by dividing the average production in the experimental period by that of the preliminary period.

TRIAL 1

(Fat percentages in grain mixtures: high-fat, 4.69; medium-fat, 3.42; low-fat, 2.79)

The summary for this trial is given in table 2. The data from 40 cows are included in the results. There were 15 cows each in the high- and low-fat groups and 10 in the medium-fat group. In this latter group it was necessary to omit the data from five of the cows because of abnormal circumstances, which could not be attributed to experimental procedure. Reasons for dropping these five cows were as follows: One cow was started on the wrong

TABLE 2.—TRIAL 1—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 50 days, all cows were fed the high-fat ration containing 4.69 per cent fat)

	Group 1	Group 2	Group 3
Number of cows	15	10	15
Production per cow, 30 days			
Milk, lb.	1,256.40	1,283.40	1,251.00
Test, per cent	3.17	3.02	3.05
Fat, lb.	39.80	38.70	38.20
Milk (4 per cent F. C. M.), lb.	1,099.60	1,093.50	1,074.00
Grain fed (30 days), lb.	398.00	424.00	411.00
Milk per lb. of grain, lb.	3.16	3.03	3.04
Liveweight gain per cow, 30 days, lb.	51.50	48.00	47.60
Average daily 4 per cent milk per cow, lb.	36.70	36.50	35.80
(Experimental period, 100 days)*			
	High fat	Medium fat	Low fat
Number of cows	15	10	15
Fat in grain mixture, per cent	4.69	3.42	2.79
Production per cow, 30 days			
Milk, lb.	1,047.00	1,030.70	1,031.00
Test, per cent	3.43	3.18	3.31
Fat, lb.	35.90	32.80	34.10
Milk (4 per cent F. C. M.), lb.	956.80	903.90	923.60
Grain fed (30 days), lb.	345.00	335.00	329.00
Milk per lb. of grain, lb.	3.03	3.08	3.13
Liveweight gain per cow, 30 days, lb.	32.00	29.70	27.00
Average daily 4 per cent milk per cow, lb.	31.90	30.10	30.80
(Differences between periods)			
Milk, lb.	−209.40	−252.70	−220.00
Test, per cent	+ .26	+ .16	+ .26
Fat, lb.	− 3.90	− 5.90	− 4.10
4 per cent milk, lb.	−142.80	−189.60	−150.40
Grain, lb.	− 53.00	− 89.00	− 82.00
Milk per lb. of grain, lb.	− .13	+ .05	+ .09
Liveweight gain, lb.	− 19.50	− 18.30	− 20.60
Average daily 4 per cent milk, lb.	− 4.80	− 6.40	− 5.00
Ratio of experimental : preliminary (4 per cent milk), per cent	87.01	82.66	86.00

*The experimental period was actually 110 days; however, the first 10 days were considered as transitional and eliminated from the data.

ration through an error; another aborted; a third had a severe attack of mastitis; and the other two went "off feed", which, as judged by the history of these two cows, was a condition probably not due to the type of grain mixture fed.

On the basis of the production of 4 per cent fat-corrected milk during the experimental period, the groups ranked as follows: high, low, and medium fat. The high-fat groups produced an average of 33.2 pounds of 4 per cent milk more per 30 days than the low-fat group. However, this difference was nearly the same as in the preliminary period, when all the cows were fed alike. The performance of the low-fat group very closely paralleled that of the high-fat group when the preliminary period was used as a basis for comparison. The medium-fat group showed the greatest decrease between the preliminary and experimental periods; the ratio was 82.7 as compared with 87.0 and 86.0 for the high- and low-fat groups, respectively.

The butterfat tests of all three groups showed a similar increase from the preliminary to the experimental period. This increase probably represents the normal for the advance in lactation and the seasonal change from summer to late fall and early winter. The higher test made by the high-fat cows during the experimental period should not be interpreted as resulting from the feeding. This same relationship existed in the preliminary period, when all cows were fed alike.

There was not much difference between the groups in liveweight gains. The average gains per 30 days were 32.0, 29.7, and 27.0 pounds for the high-, medium-, and low-fat groups, respectively. The differences were not significant, and all the gains were considered satisfactory.

In this first trial there were no consistent differences that could be attributed to the different levels of fat in the grain mixtures fed. The group on the lowest level of fat performed very nearly as did the group on the highest level. The medium-fat intake group appeared to be the poorest.

TRIAL 2

(Fat percentages in grain mixtures: high-fat, 4.77; medium-fat, 3.65; low-fat, 2.58)

Trial 2 was started immediately following the completion of the first trial and was conducted in a manner identical to that of the first one. Main points of difference between these two trials were use of all but three different cows, use of different batches of feeds, and season of the year. For this trial there were 30 cows, 10 each in the 3 groups. These cows produced at about the same level as did those in trial 1.

The summary for trial 2 is given in table 3. In the production of 4 per cent milk during the experimental feeding, the medium-fat group ranked first; the low-fat, second; and the high-fat, last. The difference between the first and last groups was 30.9 pounds. In the preliminary period, when all groups were fed alike, the group which later received the high-fat grain was first in production, followed by the medium-fat group, and the low-fat group was last. The ratios of production of the three groups between the two periods were as follows: medium-fat, 82.2; low-fat, 81.5; and high-fat, 78.7.

TABLE 3.—TRIAL 2—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 50 days, all cows were fed the high-fat ration containing 4.77 per cent fat)

	Group 1	Group 2	Group 3
Number of cows	10	10	10
Production per cow, 30 days			
Milk, lb.	1,274.50	1,260.80	1,264.00
Test, per cent	3.36	3.36	3.31
Fat, lb.	42.80	42.40	41.90
Milk (4 per cent F. C. M.), lb.	1,152.70	1,141.00	1,134.10
Grain fed (30 days), lb.	410.00	403.80	411.50
Milk per lb. of grain, lb.	3.11	3.12	3.07
Liveweight gain per cow, 30 days, lb.	— 17.30	— 16.50	— 13.90
Average daily 4 per cent milk per cow, lb.	38.40	38.00	37.80
(Experimental period, 100 days)*			
	High fat	Medium fat	Low fat
Number of cows	10	10	10
Fat in grain mixture, per cent	4.77	3.65	2.58
Production per cow, 30 days			
Milk, lb.	1,013.20	1,025.80	1,022.10
Test, per cent	3.31	3.43	3.36
Fat, lb.	33.50	35.20	34.40
Milk (4 per cent F. C. M.), lb.	907.40	938.30	924.10
Grain fed (30 days), lb.	335.90	333.60	327.50
Milk per lb. of grain, lb.	3.02	3.07	3.12
Liveweight gain per cow, 30 days, lb.	11.50	9.90	11.90
Average daily 4 per cent milk per cow, lb.	30.30	31.30	30.80
(Differences between periods)			
Milk, lb.	—261.30	—235.00	—241.90
Test, per cent	— .05	+ .07	+ .05
Fat, lb.	— 9.30	— 7.20	— 7.50
4 per cent milk, lb.	—245.30	—202.70	—210.00
Grain, lb.	— 74.10	— 70.20	— 84.00
Milk per lb. of grain, lb.	— .09	— .05	+ .05
Liveweight gain, lb.	+ 28.80	+ 26.40	+ 25.80
Average daily 4 per cent milk, lb.	— 8.10	— 6.70	— 7.00
Ratio of experimental : preliminary, per cent	78.71	82.23	81.48

*The experimental period was actually 110 days; however, the first 10 days of this were considered as transitional and eliminated from the data.

The results of this trial in butterfat test were similar to those of the first trial, in that the different fat levels in the grain mixture had no apparent effect on the fat test of the milk. In the preliminary period, when all three groups were fed alike, the tests were practically the same. In the experimental period on the different fat levels, the greatest difference in tests between groups amounted to slightly more than 0.1 per cent, and the high-fat group had the lowest test. Both the medium- and low-fat groups increased slightly in test from the preliminary to the experimental period, but the high-fat group decreased slightly. The results of this second trial differed from those of the first in showing smaller increases in tests from the preliminary to the experimental period. A possible explanation for this variation may be the difference in time of year when the work was conducted. This second trial was started in the winter and continued into the late spring, or from cold weather to warm weather. These conditions were just the reverse of those in the first trial.

The liveweight gains were practically the same for all groups during the experimental feeding. The gains were not so large as in the preceding trial, and here, again, the seasonal difference may have had its effect.

FIRST TWO TRIALS COMBINED

The results of these two trials are in general agreement in showing that the difference in fat levels in the grain mixtures made no apparent difference in production. However, very slight differences did exist between the groups, both in the preliminary and in the experimental periods. These differences did not favor the same groups in both trials. In the first trial, the high-fat group

TABLE 4.—TRIALS 1 AND 2 COMBINED—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 50 days, all cows were fed the high-fat ration containing 4.73 per cent fat)

	Group 1	Group 2	Group 3
Number of cows	25	20	25
Production per cow, 30 days			
Milk, lb.	1,265.50	1,272.10	1,257.50
Test, per cent	3.26	3.19	3.19
Fat, lb.	41.30	40.60	40.10
Milk (4 per cent F. C. M.), lb.	1,126.20	1,117.30	1,104.10
Grain fed (30 days), lb.	404.00	413.90	411.30
Milk per lb. of grain, lb.	3.13	3.07	3.06
Liveweight gain per cow, 30 days, lb.	17.10	15.80	17.80
Average daily 4 per cent milk per cow, lb.	37.50	37.20	36.80
(Experimental period, 100 days)			
	High fat	Medium fat	Low fat
Number of cows	25	20	25
Fat in grain mixture, per cent	4.73	3.54	2.69
Production per cow, 30 days			
Milk, lb.	1,030.10	1,028.30	1,026.60
Test, per cent	3.37	3.31	3.34
Fat, lb.	34.70	34.00	34.30
Milk (4 per cent F. C. M.), lb.	932.10	921.10	923.90
Grain fed (30 days), lb.	340.50	334.30	328.30
Milk per lb. of grain, lb.	3.03	3.08	3.13
Liveweight gain per cow, 30 days, lb.	21.80	19.80	19.50
Average daily 4 per cent milk per cow, lb.	31.10	30.70	30.80
(Difference between periods)			
Milk, lb.	—235.40	—244.00	—230.00
Test, per cent	+ .11	+ .12	+ .15
Fat, lb.	— 6.60	— 6.60	— 5.80
4 per cent milk, lb.	—194.10	—196.20	—180.20
Grain, lb.	— 63.50	— 79.60	— 83.00
Milk per lb. of grain, lb.	— .10	+ .01	+ .07
Liveweight gain, lb.	+ 4.70	+ 4.00	+ 1.70
Average daily 4 per cent milk per cow, lb.	— 6.40	— 6.50	— 6.00
Ratio of experimental : preliminary, per cent	82.76	82.44	83.68
(Using weighted averages in combining the trials, 30-day basis)			
Preliminary			
	Group 1	Group 2	Group 3
Milk, lb.	1,263.7	1,272.1	1,256.3
Milk (4 per cent F. C. M.), lb.	1,120.9	1,117.3	1,097.9
Experimental			
Milk, lb.	1,033.5	1,028.3	1,027.4
Milk (4 per cent F. C. M.), lb	937.0	921.1	923.8
Ratio of experimental : preliminary, per cent	83.59	82.44	84.14

appeared to lead slightly, and the medium-fat group was last, whereas in the second trial this order was reversed. In both trials the low-fat group was a close second. Averaging the results from both trials, as shown in table 4, brings out how nearly identical the results were, regardless of the different fat intakes. These results are based on 25 cows on each of the high- and low-fat grain mixtures and on 20 cows on the medium-fat mixture.

Because of the difference in the number of cows used in the two trials, it may be reasoned that weighted averages rather than straight averages should be used in combining the data from the two trials. With this method, the first trial, in which more cows were used in the high- and low-fat groups than in the second one, would receive the greater emphasis. Results of using weighted averages are shown at the bottom of table 4. This method of calculation makes only a small difference in the figures and does not change the interpretation of the results.

When the data for the experimental period are taken at their face value, the difference caused by the extremes of fat feeding as represented by the high- and low-fat grain mixtures favored the high-fat grain mixture on a 30-day basis as follows: 3.5 pounds of milk, 0.4 pound of butterfat, 8.2 pounds of 4 per cent milk, and 2.3 pounds of liveweight gain. The high-fat group tested 0.03 per cent higher than the low-fat group. These differences are small and without significance. However, the differences appear to be a reflection of those existing in the preliminary period, when all the cows were fed alike. In the preliminary period, a comparison between the same two groups showed a difference of 8.0 pounds of milk, 1.2 pounds of butterfat, and 22.1 pounds of 4 per cent milk. The difference in test between these two groups amounted to 0.07 per cent in this period. An exception was the liveweight increases. The groups subsequently fed the low-fat mixture gained 0.7 pound more than the groups subsequently fed the high-fat mixture. On the ratio basis, which amounts to the comparative production in the two periods, the low-fat group did slightly better than the high-fat group; the ratios were 83.7 and 82.8 for the low- and high-fat groups, respectively.

SECOND YEAR'S WORK

Four separate trials were conducted during the second year. Three of these were alike and similar in general plan to the trials of the first year. The other one, designated as No. 6, represented a drastic departure and will be treated separately. Of the three similar trials, two (No. 3 and 4) were conducted at the Grafton State Farm and one (No. 5) at the Experiment Station at Wooster. In outlining the general procedure during this second year, only points wherein this work differed from that of the first year will be described.

FEEDING

Grain.—Only two grain mixtures representing two levels of fat were used (table 5). The mixtures represent a high-fat level of 4.9 per cent and a low-fat level of 3.2 per cent. These levels approximate the extremes normally encountered in grain mixtures in Ohio when the usual farm feeds are used with soybeans and the soybean oil meals. For the high-fat mixture a combination of expeller soybean oil meal and ground soybeans was used as the protein supplement. For the low-fat mixture, extracted soybean oil meal was used.

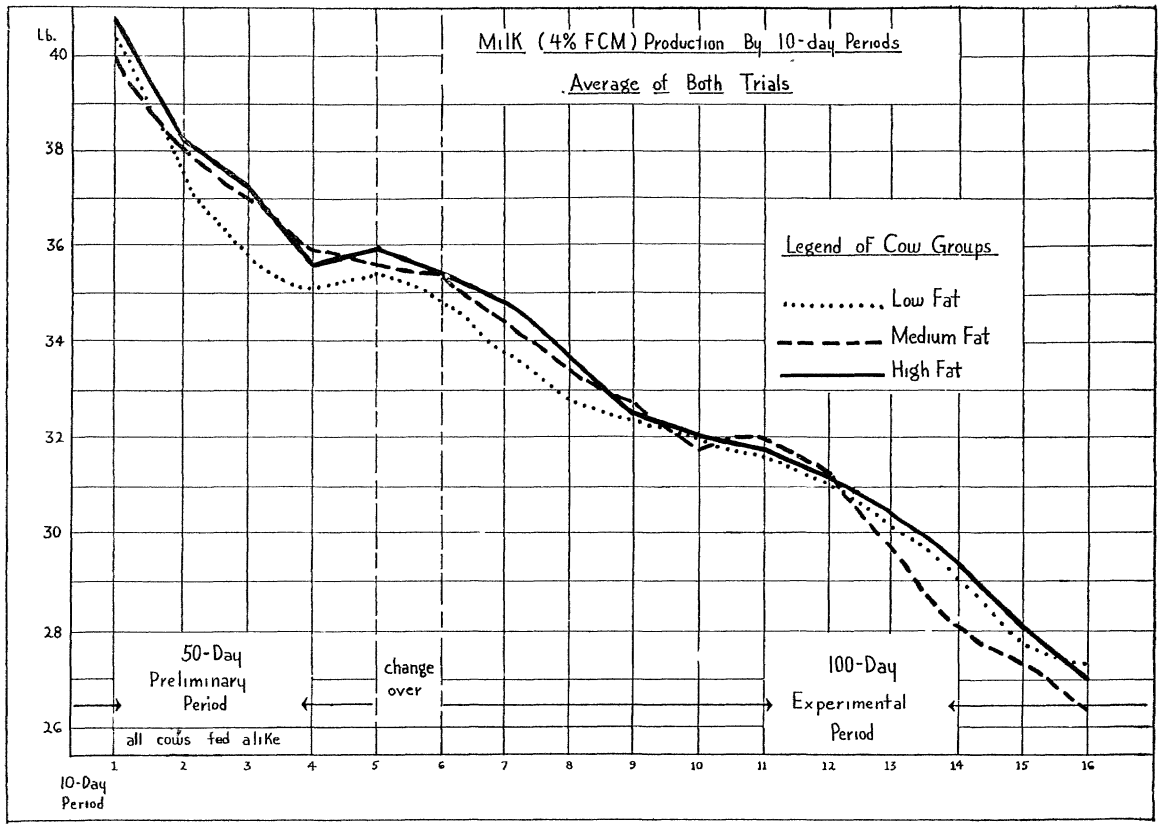

Fig. 4.—Average daily production per cow by 10-day periods for trials 1 and 2

With the exception of the differences just described and a very small difference in the amount of corn-and-cob meal, the two grain mixtures were identical. Chemical analyses of the grain mixtures and of the individual ingredients are given in appendix tables 3, 4, and 5. The points of difference between the two grain mixtures are shown in table 5. The experimental differences shown can be considered as the supplemental mixture which was added to the same basal mixture. On the basis of a ton of the feed mixtures, 120 pounds of ground soybeans and 332 pounds of expeller soybean oil meal in the high-fat mixture were balanced against 60 pounds of corn-and-cob meal and 392 pounds of extracted soybean oil meal in the low-fat mixture.

TABLE 5.—Grain mixtures used in trials 3, 4, 5, and 6

	High fat	Low fat
	Lb.	*Lb.*
Corn-and-cob meal*	850	910
Ground oats	340	340
Wheat bran	200	200
Molasses feed†	250	250
Ground soybeans	120	
41 per cent (expeller) soybean oil meal	200	
44 per cent (extracted) soybean oil meal		260
Minerals and salt‡	40	40
Total	2,000	2,000
Total protein:		
Trial 3, per cent	17.90	18.03
Trial 4, per cent	18.11	18.00
Trials 5 and 6, per cent	16.78	17.78
Average, per cent	17.60	17.94
Total fat:		
Trial 3, per cent	4.83	3.21
Trial 4, per cent	4.86	3.12
Trials 5 and 6, per cent	4.99	3.24
Average, per cent	4.89	3.19

Roughages:
First- and second-cutting alfalfa hay fed ad libitum; records of consumption kept in trials 5 and 6; corn silage, 30 lb. per day, to Holstein cows and 26 to 28 lb. to Jerseys (amounts weighed).

*Ground corn was used in place of corn-and-cob meal in trials 5 and 6.

†See table 1 footnote.

‡Minerals and salt, 40 lb. per ton of feed mixture, composed of salt, 20 lb., and dicalcium phosphate, 20 lb., for trials 3 and 4. In trials 5 and 6 steamed bone meal replaced the dicalcium phosphate.

TABLE 5A.—Experimental differences in the grain mixtures shown in table 5

	High fat	Low fat
	Lb.	*Lb.*
Corn-and-cob meal		60
Ground soybeans	120	
41 per cent (expeller) soybean oil meal	332	
44 per cent (browned extracted) soybean oil meal		392
Total differences	452	452

Hay.—Alfalfa hay, chiefly second cutting, was fed in all the trials. In trials 3 and 4, conducted at the Grafton State Farm, the amounts fed were not weighed, but in trial 5, conducted at the Experiment Station, both the amounts fed and the amounts refused were weighed.

Corn silage.—In all trials conducted the second year, all the corn silage was weighed at each feeding. All the Holstein cows received 30 pounds per day; the Jerseys received a smaller amount.

FEEDING PERIODS

The feeding periods were shortened in the second year's trial to 30 days for the preliminary[1] and 100 days for the experimental. The first 10 days of the experimental period were considered as transitional and eliminated from the final data. This reduction in length of the periods was made to permit the two Grafton trials to be carried out entirely under barn feeding conditions. Even so, it was necessary to start one trial (No. 4) before the other (No. 3) was completed. Likewise at the Experiment Station there was some overlapping in trials 5 and 6. One of the chief differences between the 2 years was in the grain mixture fed during the preliminary period, when all the cows were fed alike. In the first year, this grain was the high-fat mixture, but in the second year, it was a 50-50 blend of the high- and low-fat grain mixtures later used as the experimental mixtures. By the method used the first year, one group, the high-fat group, continued throughout the work without a change in feeding, whereas the other groups received a change in their feeding to mixtures containing smaller amounts of fat, and thus a possible carry-over effect of fat was permitted. In the second year's work this possibility was reduced to a minimum.

BUTTERFAT TESTING

Composite milk samples representing a day's production of each cow were made and tested in each 10-day period, more frequent testing than the two tests every 30 days used in the first year's trials.

TRIAL 3

(Fat percentages in grain mixtures: high-fat, 4.83; low-fat, 3.21)

The results of trial 3 are shown in table 6. There were 12 cows in each group. In the preliminary period on the blended grain mixture, group 1 averaged 78.8 pounds more milk and 1.8 pounds more fat per 30 days than did group 2. Group 1 later received the high-fat grain mixture and group 2 the low-fat.

In the experimental period this same relationship, with even larger differences, existed. The high-fat group produced 161.7 pounds more milk and 4 pounds more butterfat than did the lower fat group.

On the basis of 4 per cent milk, the differences in production amounted to 59.6 pounds in the preliminary period and 124 pounds in the experimental period; in both, the difference favored group 1, the one receiving the high-fat ration in the experimental period. It is evident that the cows receiving the high-fat grain mixture kept up better than those receiving the low-fat mixture. The ratio comparison of 96.2 for this group is extraordinary compared with that of the low-fat group, of 90.4, which represents the ordinary or expected relationship. An examination of the production of the individual

[1]This 30-day preliminary is considered as net. The cows had actually been receiving the preliminary grain mixture previously, but they were not weighed until the start of the period.

TABLE 6.—TRIAL 3—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 30 days, all cows were fed a blended grain mixture containing 3.76 per cent fat)

	Group 1	Group 2
Number of cows	12	12
Production per cow, 30 days		
Milk, lb.	1,371.80	1,293.00
Test, per cent	3.22	3.28
Fat, lb.	44.20	42.40
Milk (4 per cent F. C. M.), lb.	1,212.00	1,152.40
Grain fed (30 days), lb.	396.30	369.70
Milk per lb. of grain, lb.	3.46	3.50
Liveweight gain per cow, 30 days, lb.	36.00	55.20
Average daily 4 per cent milk per cow, lb.	40.40	38.40
(Experimental period, 90 days)		
	High fat	Low fat
Number of cows	12	12
Fat in grain mixture, per cent	4.83	3.21
Production per cow, 30 days		
Milk, lb.	1,303.30	1,141.60
Test, per cent	3.30	3.42
Fat, lb.	43.00	39.00
Milk (4 per cent F. C. M.), lb.	1,165.70	1,041.70
Grain fed (30 days), lb.	402.40	358.60
Milk per lb. of grain, lb.	3.24	3.18
Liveweight gain per cow, 30 days, lb.	20.90	16.60
Average daily 4 per cent milk per cow, lb.	38.90	34.70
(Differences between periods)		
Milk, lb.	— 68.50	—151.40
Test, per cent	+ .08	+ .14
Fat, lb.	— 1.20	— 3.40
4 per cent milk, lb.	— 46.30	—110.70
Grain, lb.	+ 6.10	— 11.10
Milk per lb. of grain, lb.	— .22	— .32
Liveweight gain, lb.	— 15.10	— 38.60
Average daily 4 per cent milk, lb.	— 1.50	— 3.70
Ratio of experimental : preliminary (4 per cent milk, 30 days), per cent	96.18	90.39

cows shows that there were five of the animals in this group having ratios of over 100 per cent, whereas in the low-fat group only one cow showed a ratio over 100 per cent.

A statistical analysis of the data indicated that the production differences were not significant.

The butterfat tests of both groups increased 0.1 per cent, and in each period, group 2 tested 0.1 per cent higher than group 1.

There was not much difference in liveweight gains although slightly better gains were made by group 1 in both periods. The gains were all very satisfactory, being between 34 and 40 pounds per 30 days.

The results of trial 3 favor the high-fat grain mixture. However, it should be pointed out that the difference appeared to be the result of extraordinary production of five of the cows on the high-fat ration, rather than of poor performance of the cows on the low-fat ration. Only one of the cows on the low-fat ration showed this remarkable production, having a ratio of 112, which was almost as good as the 113 of the highest cow in the high-fat group.

TRIAL 4

(Fat percentages in grain mixtures: high-fat, 4.86; low-fat, 3.12)

This trial was started a little before completion of the third one, in order to have the trial completed before the beginning of the pasture season. Hence, none of the 22 cows used in this fourth trial had taken part in the third one.

The summarized data for this trial are shown in table 7. The production of the cows during the preliminary period was the highest of any in the trials reported. Group 1 produced 1,464.1 pounds of milk per month and averaged nearly 49 pounds daily per cow. Although the cows of group 2 produced about 2 pounds less milk per day, they produced about the same amount of butterfat, because they had a slightly higher butterfat test.

TABLE 7.—TRIAL 4—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 30 days, all cows were fed a blended grain mixture containing 4.00 per cent fat)

	Group 1	Group 2
Number of cows	11	11
Production per cow, 30 days		
Milk, lb.	1,464.10	1,408.60
Test, per cent	3.24	3.35
Fat, lb.	47.40	47.20
Milk (4 per cent F. C. M.), lb.	1,296.40	1,271.60
Grain fed (30 days), lb.	398.00	385.90
Milk per lb. of grain fed, lb.	3.68	3.65
Liveweight gain per cow, 30 days, lb.	— 9.20	— 10.30
Average daily 4 per cent milk per cow, lb.	43.20	42.40
(Experimental period, 90 days)		
	High fat	Low fat
Number of cows	11	11
Fat in grain mixtures, per cent	4.86	3.12
Production per cow, 30 days		
Milk, lb.	1,278.90	1,270.90
Test, per cent	3.08	3.18
Fat, lb.	39.40	40.40
Milk (4 per cent F. C. M.), lb.	1,102.50	1,113.60
Grain fed (30 days), lb.	389.60	380.40
Milk per lb. of grain, lb.	3.21	3.34
Liveweight gain per cow, 30 days, lb.	11.90	14.20
Average daily 4 per cent milk per cow, lb.	36.80	37.10
(Differences between periods)		
Milk, lb.	—185.20	—137.70
Test, per cent	— .16	— .17
Fat, lb.	— 8.00	— 6.80
4 per cent milk, lb.	—193.90	—158.00
Grain, lb.	+ .60	— 5.50
Milk per lb. of grain, lb.	— .47	— .31
Liveweight gain, lb.	+ 21.10	+ 24.50
Average daily 4 per cent milk, lb.	— 6.40	— 5.30
Ratio of experimental: preliminary (4 per cent milk, 30 days), per cent	85.04	87.57

On the basis of 4 per cent milk per month, the average of group 1 was 25 pounds greater than that of group 2. Both lost slightly in liveweight during this preliminary period.

On the experimental rations the production of the two groups was practically the same. The high-fat group produced 8 pounds more milk but 1

pound less butterfat than the low-fat group. In terms of 4 per cent milk, the low-fat group averaged 11 pounds more than the high-fat group, whereas in the preliminary period this group produced less than the latter. The decline in production as shown by the differences between the two periods was a little greater on the high-fat ration than on the low-fat one. The ratios expressing this relationship are 85.0 for the high-fat, and 87.6 for the low-fat ration.

On both the experimental rations there was a decrease in the butterfat tests as compared with the tests during the preliminary period. This decrease amounted to 0.16 per cent on the high-fat, and 0.17 per cent on the low-fat ration. This same result, but less pronounced, occurred in trial 2 of the previous year, which was conducted at the same time of year. Probably the explanation given in the discussion of that trial (No. 2) is applicable here also, namely, seasonal effect. Other explanations could be advanced, but the chief consideration is that, regardless of the cause, the fat content in the grain mixture apparently made little difference in the butterfat test.

The liveweight gains were approximately the same on both experimental rations, averaging 11.9 pounds for the high-fat group and 14.2 pounds for the low-fat group.

TRIAL 5

(Fat percentages in grain mixtures: high-fat, 4.99; low-fat, 3.24)

This trial was conducted at the Experiment Station at Wooster. Although it is designated as No. 5, it was actually started before trial 4. It has been given the number 5 in order not to break the sequence of the four Grafton trials. As previously explained, the general plan of this trial was the same as that for the others, with the exception that a record was kept of the hay consumed and that some Jersey cows were used rather than all Holsteins, as in the Grafton work. It was considered desirable to repeat the work at a different location, because this repetition would not only furnish additional information, but would also present an opportunity for discovering some hidden factor or factors in the previous work that might have influenced the results.

The feed mixtures employed were the same as those used in the other trials of this year, with the exception that ground shelled corn replaced corn-and-cob meal. The feeds used in this work were from different lots than were those of the Grafton trials.

There were 12 cows used in the trial, 6 purebred Holsteins and 6 purebred Jerseys. These two breeds were equally distributed between the two groups.

Table 8 summarizes the results. During the preliminary period on the blended ration, the cows in group 2 produced 70 pounds more milk per month than those of group 1, but both groups produced the same amount of butterfat, or 45.6 pounds, as the cows in group 1 tested about 0.3 per cent higher than those in group 2. On the basis of 4 per cent milk, group 2 led by 28 pounds for the 30-day average and also gained 9 pounds more in liveweight than the cows in group 1.

After the experimental feeding started, the same general relationship between the groups continued. Group 2, changed to the low-fat ration, produced more milk and more 4 per cent milk than group 1, now on the high-fat ration. In butterfat production there was a very slight change in relationship. Butterfat production was not equal for the two groups; group 2 produced a little more than group 1. Both groups increased in test, but the increase made

by group 2, on the low-fat ration, was greater than that made by group 1, on the high-fat ration. Only in the liveweight gains was there a change in relationship. Both groups continued to gain in weight at a slower rate, but the high-fat group gained slightly more than the low-fat group.

TABLE 8.—TRIAL 5—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 30 days, all cows were fed a blended ration containing 4.08 per cent fat)

	Group 1	Group 2
Number of cows	6	6
Production per cow, 30 days		
Milk, lb.	1,022.30	1,092.90
Test, per cent	4.46	4.17
Fat, lb.	45.60	45.60
Milk (4 per cent F. C. M.), lb.	1,092.80	1,120.70
Grain fed (30 days), lb.	333.80	347.70
Hay fed (30 days), lb.	506.20	527.30
Silage fed (30 days), lb.	842.10	859.10
Milk per lb. of grain, lb.	3.06	3.14
Liveweight gain per cow, 30 days, lb.	19.50	28.50
Average daily 4 per cent milk per cow, lb.	36.40	37.40
(Experimental period, 90 days)		
	High fat	Low fat
Number of cows	6	6
Fat in grain mixtures, per cent	4.99	3.24
Production per cow, 30 days		
Milk, lb.	895.00	951.30
Test, per cent	4.52	4.39
Fat, lb.	40.40	41.80
Milk (4 per cent F. C. M.), lb.	964.20	1,007.60
Grain fed (30 days), lb.	322.30	330.70
Hay fed (30 days), lb.	490.00	559.20
Silage fed (30 days), lb.	845.60	857.40
Milk per lb. of grain, lb.	2.78	2.88
Liveweight gain per cow, 30 days, lb.	15.70	8.20
Average daily 4 per cent milk per cow, lb.	32.10	33.60
(Differences between periods)		
Milk, lb.	—127.30	—141.60
Test, per cent	+ .06	+ .22
Fat, lb.	— 5.20	— 3.80
4 per cent milk, lb.	—128.60	—113.10
Grain fed (30 days), lb.	— 11.50	— 17.00
Hay fed (30 days), lb.	— 16.20	+ 31.90
Silage fed (30 days), lb.	+ 3.50	— 1.70
Milk per lb. of grain, lb.	— .28	— .26
Liveweight gain, lb.	— 3.80	— 20.30
Average daily 4 per cent milk, lb.	— 4.30	— 3.80
Ratio of experimental : preliminary, per cent	88.23	89.91

The low-fat cows ate 69 pounds more hay than the high-fat cows. As explained, an attempt was made to feed all the cows in this work all the hay they cared to eat; the refuse was weighed back and not counted in the total consumption. The cow on the low-fat ration ate more hay than her pair-mate on the high-fat ration in five of the six pairs. The difference was not great except in one pair.

The ratio of the production of 4 per cent milk between the preliminary and experimental periods was 88.2 for the high-fat group and 89.9 for the low-fat group, not a significant difference, a result which indicates that the two grain mixtures were of about equal merit. Trial 5 can be considered as a

check test for the other four trials conducted at the Grafton Farm, as it was conducted with a different herd of cows and even included some cows of a different breed. There were also a great many other points of difference between this trial and the other four, including such items as the grains, roughage, general management of the cows, and the personnel in charge of the cows. In general, the results of this trial are in agreement with those of the other four trials in failing to show any outstanding differences as a result of the level of fat in the grain mixture.

TRIALS 3, 4, AND 5 COMBINED

(Fat percentages in grain mixtures: high-fat, 4.89; low-fat, 3.19)

The levels of fat in the grain mixtures used in these trials were slightly higher than the high and low levels used in trials 1 and 2, and there was less difference between the two levels in this series than between the extremes used in the first two trials. In round numbers, the two levels represent 0.8 per cent more and less than the 4 per cent level tentatively suggested by Maynard et al. (18).

TABLE 9.—TRIALS 3, 4, and 5 COMBINED—Summary of milk and butterfat production and liveweight gains, with feed consumption

(During a preliminary period of 30 days, all cows were fed a blended ration containing 3.95 per cent fat)

	Group 1	Group 2
Number of cows	29	29
Production per cow, 30 days		
Milk, lb.	1,286.10	1,264.80
Test, per cent.	3.55	3.57
Fat, lb.	45.70	45.10
Milk (4 per cent F. C. M.), lb.	1,200.40	1,181.60
Grain fed (30 days), lb.	376.00	367.80
Milk per lb. of grain, lb.	3.42	3.44
Liveweight gain per cow, 30 days, lb.	15.40	24.50
Average daily 4 per cent milk per cow, lb.	40.01	39.39
(Experimental period, 100 days)		
	High fat	Low fat
Fat in grain mixture, per cent	4.89	3.19
Number of cows	29	29
Production per cow, 30 days		
Milk, lb.	1,159.10	1,121.30
Test, per cent.	3.53	3.60
Fat, lb.	40.90	40.40
Milk (4 per cent F. C. M.), lb.	1,077.50	1,054.30
Grain fed (30 days), lb.	374.40	356.60
Milk per lb. of grain, lb.	3.09	3.14
Liveweight gain per cow, 30 days, lb.	16.20	13.00
Average daily 4 per cent milk per cow, lb.	35.92	35.14
(Differences between periods)		
Milk, lb.	−127.00	−143.50
Test, per cent.	− .02	+ .03
Fat, lb.	− 4.80	− 4.70
4 per cent milk, lb.	−122.90	−127.30
Grain, lb.	− 1.60	− 11.20
Milk per lb. of grain, lb.	− .33	− .30
Liveweight gain, lb.	+ .80	− 11.50
Average daily 4 per cent milk per cow, lb.	− 4.09	− 4.25
Ratio of experimental: preliminary, per cent.	89.76	89.23

The three trials of this second series are in general agreement and also agree with the two trials of the first series. The summary of these trials is shown in table 9. In the preliminary period the cows in group 1 produced more milk and slightly more butterfat and more 4 per cent milk (F. C. M.) than did the cows in group 2. The butterfat test was practically the same for both groups. Both gained in liveweight, although the gain made by group 2 was greater than that made by group 1.

In the experimental period the relationship between the two groups continued with little change, except in liveweight gain. Both groups continued to gain in liveweight, but the gains made by the high-fat cows were 3 pounds more per month than those made by the low-fat cows.

The ratios of the production of 4 per cent milk between the two periods amounted to 89.76 for the high-fat cows and 89.23 for the low-fat cows.

TRIAL 6

Like trial 5, this one was conducted at the Experiment Station at Wooster, with the same feeds and feed mixtures. Unlike trial 5 or any of the other trials, this one was of a short-time reversal type, consisting of two periods of 40 days each. Two groups of cows were fed the two grain mixtures in alternate periods. Each group consisted of one Holstein and one Jersey cow, and there was a total of four individuals in the test.

The plan of feeding was also much different in this trial. The intake of total digestible nutrients and digestible protein was limited to meet the requirements prescribed by the Haecker feeding standard. The apportionment of roughages to grain was so calculated as to have the roughages supply the requirements for maintenance and the grain the requirements for milk production. This distinction in the utilization of the nutrients within the animal body was, of course, theoretical only, as such a demarcation in the function of nutrients from different sources has never been established. It was felt that this procedure would emphasize any difference in production ability of the grain mixtures. The amounts of grain fed daily varied from 10 to 18 pounds, depending upon the quantity of milk and butterfat produced. The amounts of hay were limited to 2 to 4 pounds daily, and the corn silage to between 28 and 40 pounds, depending upon the liveweights of the individual animals. Adjustments in the rations were made at 10-day intervals and were based upon the previous 10-day production and liveweight gains or losses. Probably the outstanding feature of this system of feeding was the curtailment of the quantity of hay fed and the liberal feeding of grain.

All the cows lost in liveweight under this system of feeding, and the losses continued throughout the trial. The largest losses occurred at the beginning of the trial, covering the change from the normal system of feeding to the reduced hay feeding. Probably some of these losses represented a matter of fill, as the animals took on a "tucked up", or underfed, appearance due to lack of middle. Although none of these cows became sick, there appeared to be a change in their condition, as evidenced by rough, dull hair and tightness of hide. Also, they soon developed an abnormal craving for straw and ate large quantities of their bedding. After the first few days the bedding was changed to wood shavings.

There was no apparent difference between the two groups in their reactions to this type of feeding. Both appeared to suffer, and although the liveweight loss on the high-fat ration averaged 26 pounds whereas that on the

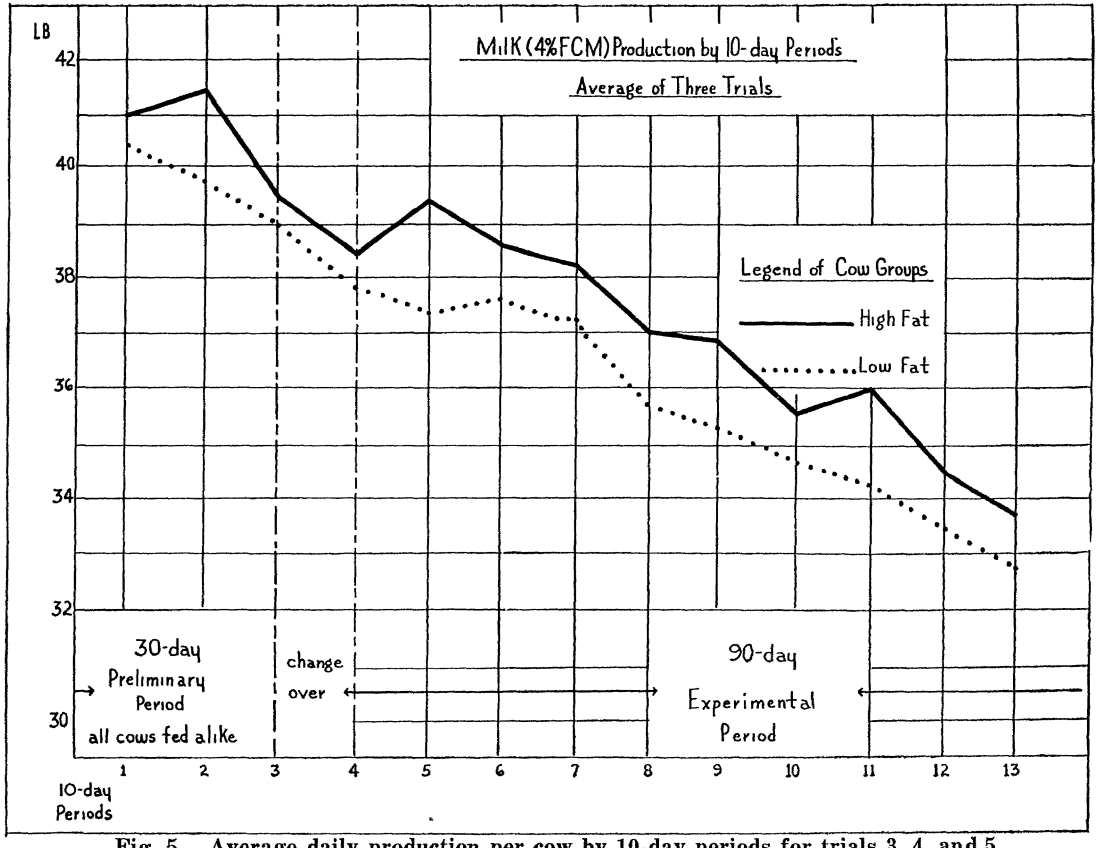

Fig. 5.—Average daily production per cow by 10-day periods for trials 3, 4, and 5

low-fat ration was 11 pounds, the difference was not significant. These losses do not seem large and in fact are not as great as the physical appearance of the animals indicated. However, together with these losses must be included those experienced during the preliminary feeding, which averaged 37 and 26 pounds for the high- and low-fat groups, respectively.

The production history of the cows was very similar to the liveweight performance; both groups declined rapidly in production from the normal preliminary feeding throughout the first experimental period, and this behavior was nearly identical on both rations. A comparison of the average daily production of 4 per cent milk during the first experimental period with that during the preliminary period gives a percentage of 81.30 for the high-fat, and 81.28 for the low-fat, group. After the groups were reversed for the second experimental period, the group receiving the high-fat ration did relatively better than the one receiving the low-fat ration. The data for the productions are presented in summarized form in table 10.

TABLE 10.—TRIAL 6—Summary of milk and butterfat production and liveweight gains, with feed consumption, 30-day reversal trial, four cows

	High fat	Low fat	Difference
Number of cows	4	4	.....
Fat in grain mixture, per cent	4.99	3.24	.....
Production per cow, 30 days			
Milk, lb.	1,197.05	1,115.80	— 81.70
Test, per cent	3.83	3.64	— .19
Fat, lb.	45.90	40.60	— 5.30
Milk (4 per cent F. C. M.), lb.	1,166.80	1,055.10	—111.70
Milk (4 per cent per day), lb.	38.90	35.20	— 3.70
Liveweight gain and loss, lb.	— 26.00	— 11.00	+ 15.00
Feed consumption			
Grain, lb.	422.80	384.30	— 38.50
Hay, lb.	82.00	81.00	— 1.00
Corn silage, lb.	975.00	975.00	.00
Milk per lb. of grain, lb.	2.83	2.90	+ .07

The average for the butterfat test was almost 0.2 per cent higher on the high-fat ration than on the low-fat ration. Of the four cows involved in this work there were two (one in each group) that gave this response. The other two cows tested exactly the same on both rations. Hence, it may be questioned as to whether the difference in test was a matter of the ration or of individuality. In fact, it appears unwise to draw any definite conclusions on the level of fat feeding from the results of trial 6. It seems evident that this type of feeding was unsatisfactory for the maintenance of liveweight or proper condition of the cows and milk production.

If a sufficiently large number of cows had been used to make the results reliable, practical application of the findings would still be doubtful, especially since short feeding periods were used. The experiences obtained in this trial suggest the importance of the role played by hay.

In the discussion to follow, the results of this sixth trial have not been considered along with the results of the other five trials. The reasons for this are apparent. Probably the most important finding in this sixth trial was that other factors may affect the results to a greater extent than the fat percentage of the grain mixture. This trial is described more as a suggestion of a possible procedure for emphasizing differences in grain mixtures than for the results obtained.

COMPOSITE RESULTS OF THE FIVE TRIALS

The results of the first five trials have been assembled in table 11. From the first year's trials, only the results of the two extremes of fat feeding have been used; the data obtained on the medium-fat ration are omitted. In the summary there are included data from a total of 108 cows, or 54 pairs.

TABLE 11.—Summary of five trials

(Preliminary period)

	Group 1	Group 2	Difference
Number of cows	54	54	
Production, 30-day basis			
Milk, lb.	1,277.8	1,261.9	15.9
Test, per cent	3.44	3.42	.02
Fat, lb.	44.0	43.1	.90
Milk (4 per cent F. C. M.), lb.	1,170.7	1,150 6	20.10
Grain fed (30 days), lb.	387.2	385.2	2.00
Milk per lb. of grain, lb.	3.30	3.28	.02
Liveweight gain per cow, 30 days, lb.	16.1	21.4	5.30
Average daily 4 per cent milk per cow, lb.	39.0	38.4	.60

(Experimental)

	High fat	Low fat	
Number of cows	54	54	
Production, 30-day basis			
Milk, lb.	1,107 5	1,083.3	24.20
Test, per cent	3.47	3 50	.03
Fat, lb.	38 4	37.9	.50
Milk (4 per cent F. C. M.), lb.	1,019.3	1,002.1	17.20
Grain fed (30 days), lb.	360.8	345.2	15.60
Milk per lb. of grain, lb.	3.07	3.14	.07
Liveweight gain per cow, 30 days, lb.	18.4	15.6	2.80
Average daily 4 per cent milk per cow, lb.	34.0	33.4	.60

Difference between periods

Production			
Milk, lb.	—170.3	—178 6	
Test, per cent	+ .03	+ .08	
Fat, lb.	— 5.6	— 5.2	
Milk (4 per cent F. C. M.), lb.	—151.4	—148.5	
Grain fed, lb.	— 26.4	— 40.0	
Milk per lb. of grain, lb.	— .23	— .14	
Liveweight gain per cow, lb.	+ 2.3	— 5.8	
Average daily 4 per cent milk per cow, lb.	— 5.0	— 5.0	
Ratio of experimental : preliminary, 4 per cent milk, per cent	87.07	87.09	

During the preliminary period, when all the cows were fed alike, group 1 (later on the high-fat ration) produced slightly more than group 2 (later on the low-fat ration). The differences amounted to almost 16 pounds of milk and 1 pound of butterfat per 30 days, or approximately 20 pounds of 4 per cent milk. The butterfat tests for the two groups were practically the same. Both groups also received the same amount of grain. In liveweight gain, group 2 exceeded group 1 by 5 pounds. These differences are all relatively small.

In the experimental period, after the cows were changed to the different fat levels, the groups continued in about the same comparative relationship as existed in the preliminary period. Differences in favor of group 1 (high-fat), calculated to a 30-day basis, amounted to 24 pounds of milk and 0.5 pound of butterfat, or 17 pounds of 4 per cent milk. These differences must be considered relatively small, and they are not mathematically significant. The

relationship between the preliminary and experimental periods for the two groups as expressed on a ratio basis is 87.07 and 87.09 for the high- and low-fat groups, respectively. Based on the performance in the preliminary period, the results, therefore, show practically no differences caused by the different levels of fat in the grain mixtures.

Even if the preliminary period is disregarded and the performance during the experimental period only is considered, the differences are too small to consider. In fact, the differences fall within the limit of experimental error and do not represent actual differences. Furthermore, in three of the five trials, the apparent differences, though small, were in favor of the low-fat ration rather than the high-fat ration, as shown by the summary of all five trials. It is evident, therefore, that the results failed to show a consistent advantage for either level of fat feeding. An analysis of the data of the pair-mates used in the several trials gives support to this view.

COMPARISON OF PAIR-MATES

As previously explained, the different groups were made up by matching or pairing the individual cows. An attempt was made to have the pairs, or sets of three as in the first year's work, as nearly alike as possible. The cows were matched in stage of lactation, gestation, liveweight, and milk production in the preliminary period. The individuals of the pair or set were then assigned to a group. After the groups were formed, one of the experimental rations was assigned to the group by a method of chance. The treatment for all the animals was the same except the grain mixture fed. A "qualitative" analysis of the data can be made by comparing the ratios of the pair-mates on the two levels of fat. This analysis is presented in table 12.

TABLE 12.—Comparison of pairs in the five trials (ratio basis)

Trial No.	Number of pairs	Favored high-fat	Favored low-fat	Equal ratios
1	15	8	6	1
2	10	5	5	0
3	12	9	3	0
4	11	4	6	1
5	6	2	4	0
Total	54	28	24	2

Of the 54 pairs included in the 5 trials, there were 28 in which the individual receiving the high-fat ration had a higher ratio than her pair-mate on the low-fat ration. In 24 pairs, the low-fat pair-mate was ahead. There were two pairs in which the pair-mates had the same ratios. Hence, according to this method of analysis also, there appeared to be no difference resulting from feeding the different levels of fat, for the number favoring the high-fat ration was only one more than half the number of pairs. Without any difference in feeding, it could be expected that the pairs would be about equally divided.

An examination of table 12 shows that this equality of distribution existed in four of the five trials. In two of the five the number favoring the high-fat ration was greater; in two others the low-fat ration was favored. In the remaining trial the pairs were equally divided, 5 to 5. Of the five trials, there was only one in which the division was very far out of balance. This was trial No. 3, in which the proportion was 9 favoring the high-fat, and 3 the low-fat

ration. As explained in the description of this trial, this difference was due to an extraordinary performance of the cows on the high-fat ration rather than to a poor showing of the cows on the low-fat ration.

This qualitative analysis of the performance of the pair-mates confirms the quantitative summary of the data. The differences in performance of the individual pair-mates on the two grain mixtures were about equally balanced. Hence, the difference in fat intake supplied by the two grain mixtures was without apparent effect.

GENERAL OBSERVATIONS

So far in this report, production has been the chief consideration. In general, production can be considered an indication of the animal's health and general well-being, especially if sufficient time is allowed for the production test. However, substantiating evidence as gained by personal observations and the health history is of value in comparing rations. A good opportunity for making such observations was presented during the first year's work with the Grafton State herd, when not only the cows on the milk production trials, but also the entire herd, were fed the experimental rations for the year. The cows not on the production test were divided into groups at the same time as the cows on test, and reallotments were made later at the start of the second trial. These groups were made up of cows that were dry or either too early or too late in lactation to be suitable for milk production comparison. The feeding of these additional cows has merely widened the scope of the work, and, although the results cannot be presented in as concrete a form as the production results, the information obtained from this feeding is of value in a general way.

PHYSICAL APPEARANCE AND GENERAL HEALTH

Although it is difficult to evaluate physical appearance because of lack of a standard of measurement, the experienced herdsman can detect differences in condition between animals. In doing this he bases his judgment on a number of factors, such as degree of fleshing, condition of hide, hair coat, expression of the eyes, appetite, and general behavior of the animals. When animals in the same herd are fed simultaneously on different rations, the observations are especially useful in revealing differences due to the manner of feeding. In conducting these five trials and in the feeding of the entire Grafton State herd for a year, repeated observations were made on the physical condition of the cows by the men directly in charge of the work and by others. Briefly, it was impossible to detect any consistent difference in the physical appearance of the different groups. This observation does not mean that all the cows showed the same degree of physical fitness, but rather that the same variations existed in each. The general health history of the cows was satisfactory, and considering the large numbers of cows involved, there was relatively little trouble. Cases of mastitis and udder "flare ups" did occur, but they happened on all rations. There appeared to be no relationship between the level of fat being fed and udder trouble.[2] Some digestive disturbances did occur, but these happened on each level of fat feeding. During the first year there were two cows

[2]Physical examinations of the cows and bacteriological and chemical tests were made of the milk from the cows on the experimental rations by Dr. A. F. Schalk and Dr. J. H. Helwig of this Station.

in the Grafton herd that aborted. One of them was receiving the high-fat ration at the time and the other the medium-fat ration. Both were negative to Bang's test.

CALVING DATA

During the first year's work with the Grafton State herd, the dry cows were fed the experimental grain mixtures practically up to freshening time. With this procedure, some of these cows had received a particular grain mixture for 3 months and longer previous to calving. In general, there appeared to be no difference in the condition of the groups at freshening that could be attributed to the prefreshening treatment. Neither did there appear to be any difference in the health or vigor of the newborn calves. In table 13 the birthweight and height at the withers of the newborn calves are given. Only the data for calves whose dams had received the experimental rations for at least 30 days previous to freshening are given. The differences shown in the table were not significant. The calves were all above normal in both weight and height.

TABLE 13.—Birthweight and height at withers of calves dropped on the three rations, averages

Ration	Males			Females		
	Calves	Weight	Height	Calves	Weight	Height
	Number	*Lb.*	*In.*	*Number*	*Lb.*	*In.*
High fat	15	106.3	30.6	11	97.8	29.9
Medium fat	6	108.5	31.1	8	104.4	30.7
Low fat	10	108.8	31.0	3	104.0	30.3

DISCUSSION

Chief reason for undertaking this study was to determine the extent to which milk and butterfat production would be affected by such moderate differences in fat intake as are commonly encountered when practical grain mixtures are fed. In brief, the point at issue has been the application of the fat question to practical feeding conditions, especially those existing in Ohio. In order to carry out this purpose, the grain mixtures used were composed of natural feeds and by-product feeds available on the market and commonly used. However, it should be recognized that when grain mixtures are made up by this method, the resulting mixtures may differ slightly in points other than just the percentage of fat. Thus, in the work under consideration, the different fat levels have been obtained by using soybeans, expeller soybean oil meal, extracted soybean oil meal, and combinations of the first two. These feeds differ not only in their fat content, but also in the treatment to which they have been subjected. The results obtained in feeding them, therefore, represent an over-all effect, not merely one of fat content. There were other small differences between the grain mixtures, in the amount of ground corn used.

The problem of obtaining grain mixtures exactly comparable in all respects, except fat content, could, theoretically, be solved by removing all or part of the fat from the entire grain mixture or from a portion of the mixture. However, in practice, the fat solvent will remove substances other than fat

and substances dissolved in the fat. Treatment by the expeller or hydraulic process to remove the fat will also remove substances soluble in the fat, so that even when such a procedure is followed, there may be some question regarding the application of the results to fat alone. A practical difficulty may also be the inability to remove the last traces of the solvent. Obtaining experimental fat levels by the addition of fat or oil to feeds may not be entirely satisfactory either, because the added fat or oil will not be dispersed in the same manner as that found naturally in feeds. There is some question about the utilization of such artificially added fat or oil.

After careful consideration of the procedure to be followed in formulating grain mixtures to represent different levels of fat, it was decided to follow a procedure similar to that which the practical feeder would probably use. The usual plan to increase the fat content of a grain mixture is to add feeds or by-product feeds of high fat content to replace or supplement those of low fat content. In the trials here described, this was essentially the system used, and the results obtained by using the system are probably more applicable to ordinary feeding than if the fat levels had been obtained by extracting the grain mixtures to reduce their fat content. However, the difference in results obtained by the use of practical feeding mixtures cannot be interpreted as being due to fat alone. Stated in another way, this work does not give a specific or academic answer to the question of the fat requirement for milk production. It does give a practical answer in terms of the way the question is answered in actual feeding.

In evaluating the results obtained in feeding trials, consideration should be given to the experimental methods and the conditions under which the results were obtained, especially in feeding trials involving dairy cows, because of the nature of the experimental subjects and the complicated feeding. With this in mind, it seems important to review several features of the trials that have been described. These features may or may not have had an influence on the results, but they should be considered, especially in view of the practical application of the results.

The use of natural grains.—It is generally economical for the dairyman to include a proper amount of farm-grown grains in the dairy grain mixture. In Ohio, where corn and oats are grown rather extensively, these grains are generally included in the grain mixture either with a 32 per cent commercial mixed feed or with the straight protein supplements, with or without wheat bran. In the grain mixtures used in the experimental work here described, approximately 60 per cent of the total mixtures was composed of corn and oats, and there was a larger amount of corn than of oats. Yellow corn was used exclusively.

The use of fresh grain mixtures.—Because of the large number of cows being fed, it was necessary to renew the experimental grain mixtures at frequent intervals (4 to 10 days), and during the course of the trials, fresh shipments of the other constituents of the mixtures were used. Whether the use of freshly ground and mixed feed has had any effect on the results is not known. It is known that feeds stored in the ground condition may undergo some changes. Throughout Ohio, grain mixtures are fed comparatively fresh, and the farm grains are ground as needed.

The feeding of roughages.—The policy followed in this work has been to give the cows all the hay they cared to eat. Hay contains very little true fat; hence the amount of hay in the ration should have but little bearing on the fat

problem, especially if it is a matter of quantity of fat only. Obtaining the results under conditions of unrestricted hay feeding seemed to approximate practical feeding. The different lots of hay fed in the trials were about average in quality, so that probably the hay consumption of the cows was close to a normal amount.

The feeding of corn silage has been uniform throughout all five of the trials. What effect, if any, this feed has had on the results is impossible to state. Nevertheless, the use of this roughage is an important feature of the feeding and must be considered. Corn silage made from well-eared corn may contain a high percentage of grain.

Length of feeding periods.—In this work the experimental grain mixtures were fed continuously to the groups for 110 days in the first year's work and 100 days in the second. These comparatively long feeding periods were chosen in order to approximate as nearly as possible under experimental conditions the usual barn feeding period. Of course, this period will vary from year to year and will also vary with the locality, but it generally lasts for 150 days and longer in this State. Although the feeding periods used in the trials do not quite duplicate the practical, it is believed that the length of time was sufficient so that the results obtained within the periods should be applicable to ordinary feeding from a time standpoint.

Treatment of the cows and the level of production.—In general, the care given the cows was about that which the ordinary good dairyman would want to give his herd. Probably the most important exception to this was that in four of the five trials here reported, the cows were fed and milked three times a day. This had been the usual practice in the Grafton herd, and for the production level of the herd, three-times-a-day milking was regarded as a desirable practice. The average production in this herd was about 12,000 pounds of milk per year. This may be considered a good production and is a fairly high standard, even for the better commercial herds. It seems reasonable to assume that the results obtained at this level of production would be applicable to production levels below this level. For levels of production above this, the assumption may be hazardous. However, the relatively few herds exceeding this level are primarily interested in making records and are fed accordingly.

The general care and management given the Grafton herd during the experimental work were little, if any, different from those to which it had been accustomed. Included in the management was the summer pasture program preceding the experimental feeding both years.

Character of fat increments.—The increased amount of fat in the higher fat mixtures has been obtained from a single source, namely, soybeans. This fat or oil has been added both in a natural form, in ground raw soybeans, and in a processed form, in the expeller and extracted soybean oil meals; the extracted meal, of course, contributed only small amounts of oil. These supplemental differences are grouped in tables 1 A and 5. Hence the results of these trials should be interpreted on the basis of a single fat differential, soybean fat or oil as found in feeds, and the results here obtained may not apply to fat derived from another source or sources. However, Maynard and coworkers (14) concluded that soybeans could be used as a source of fat in a dairy grain mixture. That the source of the fat may have some bearing on the fat levels is suggested by work done on feeding fats and oils (1, 2, 7, 10, 23).

For evaluating the results of this work, all these features should be considered, especially in the light of the practical application of the results. The conclusions drawn from these results are made on the basis of the conditions under which the results were obtained. Just how the outcome of this work has been influenced by these conditions cannot be stated, because these conditions have not been tested. The important point is that the conditions here prevailing were for the most part similar to those existing in common practice. Hence, it is hoped that the results show the practical answer to the fat question as it affects dairy herds in Ohio. The results cannot be interpreted as an academic answer to the fat question, because in the grain mixtures that have been used, the experimental differences have not been limited to fat alone. The differences have been as closely limited as possible, though secured on practical feeds.

To some it may seem that the results here obtained may be at variance with those obtained, in general, by Maynard and coworkers. However, a careful examination of the various fat levels employed by these workers and of the fat levels in this work will show that Maynard and coworkers employed more extreme differences in the fat percentages of the grain mixtures. Hence, the present results do not necessarily represent a decided disagreement, in view of the relatively small differences in production shown by Maynard and coworkers with greater extremes in fat levels. Furthermore, in the work reported the results have been obtained under conditions of feeding and management that differed somewhat from those described by the other investigators.

The question of the fat content of dairy grain mixtures may, and often does, involve a financial consideration. The increased demand and the market value of oil and fats have led to the development of highly efficient methods of removing the fat from the oil-producing seeds. As a consequence, the remaining by-product feed is low in fat. It is entirely possible that feeds and grain mixtures low in fat may sell for less than those of higher fat content. In fact, in this work, the low-fat mixtures were actually less expensive than the high-fat mixtures. Of course, the differential in selling price between high- and low-fat grain mixtures or supplements will fluctuate. Prices quoted on feeds may change between the time a work is written and the time it appears in print. Because of the increased cost, high-fat grain mixtures should result in higher production, or their use can hardly be justified from a profit standpoint. As an illustration: When high-fat grain mixtures cost 25 cents more per hundredweight than low-fat mixtures, the increased feed cost will amount to $7.50 per year for each cow, provided grain is fed at the same rate as in the trials reported. If milk would sell at $3.00 per hundredweight on a 4 per cent basis, the high-fat grain mixture would need to result in an increase in production of 250 pounds of milk per year for each cow to pay for the increased cost of the grain. The profit to be derived from the increased fat feeding would come from the increased production beyond 250 pounds of milk.

SUMMARY

Five feeding trials divided into 2 series and involving a total of 128 cows were conducted in order to determine the effect of different levels of fat in the grain mixtures on milk and butterfat production. The grain mixtures used contained only natural and by-product feeds commonly used in practice. The various fat levels were obtained, with some slight exceptions, by supplementing basal mixtures with either 41 per cent (expeller) soybean oil meal, both with and without ground soybeans, or 44 per cent (browned extracted) soybean oil meal. Because of differences between the supplements other than fat, and inherent in them, the experimental variables between the rations were not limited to fat only. However, as pointed out in the discussion, the rations were designed to obtain the answer to the fat problem in the same manner as feeders must meet it. As implied, the differences in fat levels were confined to a single kind of fat or oil, namely, that supplied by soybeans.

The continuous type of feeding trial was employed in all five of the trials summarized. In the first series of two, the preliminary period was continued for 50 days and the experimental period for 110 days, whereas in the second series of three trials, the preliminary period was 30 days and the experimental period 100 days.

In the first series, three groups of cows were fed on three levels of fat in the grain mixtures as follows: high-fat, 4.73 per cent; medium-fat, 3.54 per cent; and low-fat, 2.69 per cent.

In the second series, two groups of cows were fed on two levels of fat as follows: high-fat, 4.89 per cent; and low-fat, 3.19 per cent.

With the exception of six Jerseys used in one trial in the second series, the cows were all Holsteins of fairly high milk-producing ability.

In the first series of two trials involving 70 cows fed on three levels of fat, the average production of 4 per cent (F. C. M.) milk per 30 days was: pounds, high-fat, 932.1; medium-fat, 921.1; and low-fat, 923.9. These small differences become even smaller when interpreted in the light of the preliminary period. The ratios of production between the experimental and preliminary periods were as follows: high-fat, 82.76; medium-fat, 82.44; low-fat, 83.68.

In the second series of three trials involving 58 cows fed the two levels of fat, the average production of 4 per cent (F. C. M.) milk per 30 days was: pounds, high-fat 1,077.5; low-fat, 1,054.3. The difference of 23.2 pounds between the two groups and favoring the high-fat exceeds by 4.4 pounds the difference between the groups during the preliminary period, when all the cows were receiving the same ration. The ratios of production between the experimental and preliminary periods were as follows: high-fat, 89.76; low-fat, 89.23.

Of the 54 pairs of cows used in the 5 trials to compare the high- and low-fat rations, there were 28 pairs in which the cow on the high-fat ration had a higher ratio than her low-fat pair-mate. There were 24 pairs in which the reverse was true. In two of the pairs there was no difference between the pair-mates.

The butterfat tests and liveweight gains were apparently not affected by the fat levels in the feed.

There was also no noticeable difference in palatability in the grain mixtures used. There was no noticeable difference in their effect on the general health and condition of the cows or in preventing or causing udder trouble.

In the limited number of cases in which cows had received the different grain mixtures for some time previous to freshening, size, weight, and vigor of the newborn calves were apparently not affected by the grain mixtures used.

CONCLUSION

Under the conditions of these trials, no significant differences were observed in the production of milk, butterfat, or 4 per cent (F. C. M.) milk or in the general health of milking cows from the feeding of practical grain mixtures ranging in average fat percentage from 4.89 to 2.69.

APPENDIX

APPENDIX TABLE 1.—Chemical analysis of the feed mixtures and ingredients, trial 1

(First preliminary period, June 11-July 30, 1939)

Feed	Dry matter	Fat	Ash	Crude fiber	Protein
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn-and-cob meal	87.23	2.81	1.47	7.45	7.59
Oats	88.60	3.74	3.57	12.80	11.10
Bran	88.45	3.78	6.42	10.80	15.54
Linseed oil meal	90.08	5.29	5.78	7.51	33.28
Ground soybeans	89.37	16.92	4.12	4.49	36.62
Expeller soybean oil meal-beet pulp-molasses	85.41	2.31	6.37	7.75	25.83
Total mix, basal ration	88.70	4.71	4.56	9.29	15.11
(First experimental period, July 31-November 17, 1939)					
Corn-and-cob meal	88.20	3.56	1.54	6.35	7.72
Oats	90.37	3.04	3.58	12.38	11.25
Bran	90.12	3.73	6.36	10.65	16.50
Linseed oil meal	90.08	5.29	5.78	7.51	33.28
Ground soybeans	92.04	18.88	4.18	5.08	40.04
Expeller soybean oil meal-beet pulp-molasses	90.57	2.92	5.54	8.59	24.72
Extracted soybean oil meal-beet pulp-molasses	88.82	.65	5.64	7.90	28.16
Expeller soybean oil meal	91.61	5.54	4.84	5.87	45.09
Extracted soybean oil meal	90.99	.72	5.33	5.39	47.91
High-fat mix, basal	90.59	4.69	3.95	8.54	15.19
Medium-fat mix (expeller meal)	90.92	3.42	4.00	8.85	15.78
Low-fat mix (extracted meal)	90.05	2.79	3.90	8.49	16.07

APPENDIX TABLE 2.—Chemical analysis of the feed mixtures and ingredients, trial 2

(Second preliminary period, November 18-December 27, 1939)

Feed	Dry matter	Fat	Ash	Crude fiber	Protein
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn-and-cob meal	86.67	2.94	1.29	7.11	7.75
Oats	91.86	3.92	3.79	11.56	12.50
Bran	90.04	2.70	7.01	9.73	14.80
Linseed oil meal	88.87	6.62	5.20	8.36	32.94
Ground soybeans	94.46	16.17	4.23	7.07	37.63
Expeller soybean oil meal-beet pulp-molasses	93.41	3.08	5.03	8.59	26 75
Basal mix	91.07	4.65	4.34	8.67	14.81
(Second experimental period, January 7-April 25, 1939)					
Corn-and-cob meal	86.05	3.28	1.52	6.70	7.19
Oats	88.93	3.56	3.68	11.67	12.91
Bran	88.26	2.25	6.54	10.15	15.50
Linseed oil meal	88.87	6.62	5.20	8.36	32.94
Ground soybeans	92.57	17.02	3.40	6.60	38.00
Expeller soybean oil meal-beet pulp-molasses	85.33	3.23	5.66	7.96	25.25
Extracted soybean oil meal-beet pulp-molasses	86.96	.42	5.82	6.80	28.42
Expeller soybean oil meal	89.48	5.69	5.22	5.68	43.63
Extracted soybean oil meal	90.04	.66	5.55	5.46	46.82
High-fat mix, basal	88.00	4.77	4.39	7.43	15.94
Medium-fat mix, expeller	87.62	3.65	4.73	8.00	15.50
Low-fat mix, extracted	86.99	2.58	4.16	9.05	15.63

APPENDIX TABLE 3.—Chemical analysis of the feed mixtures and ingredients, trial 3

(Preliminary period, September 27-October 26, 1940)

Feed	Dry matter	Crude fat	Ash	Crude fiber	Protein
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn-and-cob meal	90.15	3.65	1.32	5.03	8.63
Oats	91.81	4.23	5.80	13.91	11.94
Wheat bran	92.63	4.61	3.60	10.51	17.88
Ground soybeans	93.53	19.69	4.67	4.86	38.06
Expeller soybean oil meal-beet pulp-molasses	91.28	3.20	5.92	8.59	25.13
Extracted soybean oil meal-beet pulp-molasses	90.22	.73	5.55	9.28	30.25
Expeller soybean oil meal	93.86	5.59	5.58	6.68	44.69
Extracted soybean oil meal	92.01	.98	5.71	6.29	45.88
Steamed bone meal	96.40	3.30	81.30	.80	7.10
Blended mixture	91.16	3.76	4.94	7.46	17.44
(Experimental period, October 27-February 3, 1941)					
Corn-and-cob meal	Sample	spoiled			
Oats	93 40	4.42	3.98	12.28	12.25
Wheat bran	92.63	4.61	3.60	10.51	17.88
Ground soybeans	93.53	19.69	4.67	4.86	38.06
Expeller soybean oil meal-beet pulp-molasses	91.76	3.49	5.81	8.22	27.57
Extracted soybean oil meal-beet pulp-molasses	90.63	.74	5.59	8.59	29.75
Expeller soybean oil meal	93.81	5.73	5.64	6.49	44.19
Extracted soybean oil meal	91.93	.85	5.90	6.10	45.92
Steamed bone meal	96.40	3.30	81.30	.80	7.10
High-fat mixture	91.91	4.83	5.03	6.40	17.90
Low-fat mixture	91.66	3.21	4.95	6.62	18.03

APPENDIX TABLE 4.—Chemical analysis of the feed mixtures and ingredients, trial 4

(Preliminary period, December 26, 1940-January 24, 1941)

Feed	Dry matter	Crude fat	Ash	Crude fiber	Protein
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn-and-cob meal	Sample	spoiled			
Oats	92.72	4.26	3.91	11.82	12.44
Wheat bran	92.63	4.61	3.60	10.51	17.88
Ground soybeans	93.53	19.69	4.67	4.86	38.06
Expeller soybean oil meal-beet pulp-molasses	92.24	3.77	5.69	7.84	30.00
Extracted soybean oil meal-beet pulp-molasses	91.04	.74	5.63	7.90	29.25
Expeller soybean oil meal	93.75	5.86	5.70	6.30	43.69
Extracted soybean oil meal	91.84	.72	6.08	5.91	45.95
Steamed bone meal	96.40	3.30	81.30	.80	7.10
Blended mixture	91.50	4.00	5.01	5.79	18.17
(Experimental period, January 25-May 4, 1941)					
Corn-and-cob meal	Sample	spoiled			
Oats	93.80	4.80	3.84	10.37	11.50
Wheat bran	92.63	4.61	3.60	10.51	17.88
Soybeans, ground	94.11	16.22	4.74	5.77	39.69
Expeller soybean oil meal-beet pulp-molasses	92.24	3.77	5.69	7.84	30.00
Extracted soybean oil meal-beet pulp-molasses	91.04	.74	5.63	7.90	29.25
Expeller soybean oil meal	93.75	5.86	5.70	6.30	43.69
Extracted soybean oil meal	91.84	.72	6.08	5.91	45.95
Steamed bone meal	96.40	3.30	81.30	.80	7.10
High-fat mixture	91.97	4.86	5.01	5.63	18.11
Low-fat mixture	91.44	3.12	4.99	5.50	18.00

APPENDIX TABLE 5.—Chemical analysis of the feed mixtures and ingredients, trials 5 and 6

(Preliminary period)

Feed	Dry matter	Crude fat	Ash	Crude fiber	Protein
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn, ground	92.31	4.46	1.33	2.12	9.44
Oats	95.50	4.83	4.13	10.08	10.25
Wheat bran	94.01	4.51	6.99	10.87	18.31
Soybeans, ground	95.32	18.36	4.78	5.44	37.06
Expeller soybean oil meal-beet pulp-molasses	91.20	3.44	6.01	9.06	24.81
Extracted soybean oil meal-beet pulp-molasses	90.20	.56	5.85	7.71	27.13
Expeller soybean oil meal	94.55	5.86	6.09	7.22	40.81
Extracted soybean oil meal	95.59	.59	5.80	5.94	46.56
Steamed bone meal	96.40	3.30	81.30	.80	7.10
Blended mixture	90.13	4.08	4.53	5.76	15.63
(Experimental period)					
Corn, ground	92.25	4.13	1.34	2.72	9.10
Oats	95.93	4.52	4.18	11.58	10.16
Wheat bran	94.01	4.51	6.99	10.87	18.31
Soybeans, ground	95.32	18.36	4.78	5.44	37.06
Expeller soybean oil meal-beet pulp-molasses	91.20	3.44	6.01	9.06	24.81
Extracted soybean oil meal-beet pulp-molasses	90.20	.56	5.85	7.71	27.13
Expeller soybean oil meal	94.55	5.86	6.09	7.22	40.81
Extracted soybean oil meal	95.59	.59	5.80	5.94	46.56
Steamed bone meal	96.40	3.30	81.30	.80	7.10
High-fat mixture	92.13	4.99	5.01	6.14	16.78
Low-fat mixture	91.62	3.24	4.67	5.80	17.78

APPENDIX TABLE 6.—Cows used in trials 1, 2, 3, 4, and 5. Average age, state of lactation and gestation, and liveweights at the beginning of the trials

Trial No.	Cows, number	Average age Yr.	Mo.	Lactation days	Cows bred	Liveweight, lb.
High-fat groups						
1	15	4	8	122	3	1,145
2	10	3	7	78	0	1,246
3	12	4	9	112	3	1,175
4	11	4	5	45	0	1,250
5	6	6	9	118	2	1,132
Total	54	21	38	475	8	5,948
Average	.....	4	10	95	1.6	1,190
Medium-fat groups						
1	10	4	5	117	2	1,122
2	10	4	7	111	1	1,271
Total	20	8	12	228	3	2,393
Average	.....	4	6	114	1.5	1,197
Low-fat groups						
1	15	4	7	91	2	1,082
2	10	3	7	98	1	1,209
3	12	4	10	121	5	1,254
4	11	3	5	46	0	1,179
5	6	5	8	93	0	1,163
Total	54	19	37	449	8	5,887
Average	.....	4	5	90	1.6	1,117

LITERATURE CITED

1. Allen, N. N. 1934. The fat percentage of milk as affected by feeding fats to dairy cows. Jour. Dairy Sci. 17: 5: 379-395.
2. ———— and J. B. Fitch. 1941. The influence of sustained high fat intake upon milk fat production. Jour. Dairy Sci. 24: 6: 516-517.
3. Association of Official Agricultural Chemists. 1935. Official and tentative methods of analysis. Assoc. of Off. Agr. Chemists. Washington, D. C.
4. Bartlett, M. S. 1935. An examination of the value of covariance in dairy cow nutrition experiments. Jour. Agr. Sci. 25: 238-244. Part 2.
5. Cannon, C. Y., N. K. Williams, and D. L. Espe. 1942. Cows are a good bean market. Iowa State College Farm Science Reporter 3: 1: 14-16.
6. Espe, Dwight. 1938. Secretion of Milk. 186-196. Collegiate Press, Inc. Ames, Iowa.
7. Garner, Frank H., and G. H. Sanders. 1938. A study of the effect of feeding oils to dairy cows and of the value of the Latin Square layout in animal experimentation. Jour. Agr. Sci. 28: 541-666. Part 4.
8. Gibson, Gale, and C. F. Huffman. 1939. The influence of different levels of fat in the ration upon milk and fat secretion. Mich. Agr. Exp. Sta. Quart. Bull. 21: 4: 258-264.
9. Hale, E. B., C. W. Duncan, and C. F. Huffman. 1940. Rumen digestion in the bovine with some observations on the digestibility of alfalfa hay. Jour. Dairy Sci. 23: 10: 953-967.
10. Hill, O. J., and L. S. Palmer. 1938. A study of the relation of the feed consumed by the cow to the composition of milk fat and the properties of butter. Jour. Dairy Sci. 21: 9: 529-544.
11. Huffman, C. F. 1941. Fat relations in dairy ration. Flour and Feed 42: 2: 32.
12. Jordan, W. H., and C. G. Jenter. 1897. The source of milk fat. N. Y. Agr. Exp. Sta. Bull. 13: 2: 455-456.
13. ————, ————, and F. D. Fuller. 1901. The food source of milk fat: with studies on the nutrition of milch cows. N. Y. Agr. Exp. Sta. Bull. 197.
14. Maynard, L. A., Karl E. Garner, and Adrian Hodson. 1939. Soybeans as a source of fat in the dairy ration. Cornell Univ. Agr. Exp. Sta. Bull. 722.
15. ————, J. K. Loosli, and C. M. McCay. 1940. Further studies of the influence of fat intake on milk and fat secretion. The American Soc. An. Prod. Proc. Thirty-Third Ann. Meeting, 1940. 340-344.
16. ————, ————, and ————. 1941. III. Further studies of the influence of different levels of fat intake upon milk secretion. Cornell Univ. Agr. Exp. Sta. Bull. 753.
17. ———— and C. M. McCay. 1932. The influence of different levels of fat intake upon milk secretion. Cornell Univ. Agr. Exp. Sta. Bull. 543.

18. ————, ————, H. H. Williams, and L. L. Madsen. 1934. II. Further studies on the influence of different levels of fat intake upon milk secretion. Cornell Univ. Agr. Exp. Sta. Bull. 593.

19. ———— and W. I. Myers. 1918. The refinement of feeding experiments for milk production by the application of statistical methods. Cornell Univ. Agr. Exp. Sta. Bull. 397.

20. Monroe, C. F. 1938. Soybeans and soybean products as feed for dairy cattle. Proc. Amer. Soybean Assn. 18th Ann. Meeting.

21. Schubert, A. R., and J. G. Wells. 1940. The effect of replacing solvent-extracted soybean oil meal with soybeans in a low fat ration. Mich. Agr. Exp. Sta. Quart. Bull. 23: 2: 72-73.

22. Snedecor, George W. 1937. Statistical Methods. Collegiate Press, Inc. Ames, Iowa.

23. Sutton, T. S., J. B. Brown, and E. W. Johnston. 1932. The effect of corn oil on milk and butter fat production and on the composition of butter fat in the dairy cow. Jour. Dairy Sci. 15: 3: 209-211.